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Special Sahelian Office

THE RESPONSE OF PASTORAL NOMADS TO DROUGHT IN THE ABSENCE OF OUTSIDE INTERVENTION

Douglas L. Johnson **

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* The views expressed in the study are those of the author and do not necessarily reflect those of the United Nations.

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Western Africa is in the throes of one of the worst droughts that have gripped the area since 1913. All segments of society are to some degree affected, but the burden is distributed unequally among the region's various life styles. Although pastoral nomads possess a modus operandi specifically designed to cope with conditions that are too harsh and too marginal for most agriculturalists, prolonged drought has a devastating effect on nomadic life. Since pastoral nomadism represents a productive resource use system making important contributions to the economies of many underdeveloped or developing areas (Stauffer, 1965), an understanding of its typical behavior patterns and its ecological role in the semi-arid and arid regions of West Africa is essential to any program designed to bring both immediate and long-term relief to the present drought stricken region.

This paper is based on a review, whose major conclusions are summarized elsewhere (Johnson, 1969), of more than four hundred books and articles in the French, German, and English nomadic studies literature; this body of research deals with the ecological organization and migration patterns of pastoral nomadism in North Africa and Southwestern Asia. Understandings gained from this general review offer valuable insights into the nomadic response to drought, although the literature exhibits a general lack of interest in specific nomadic responses to extreme events. Of the case studies drawn on for the present statement, four, those considering the

Tuareg (both Saharan and Sahelian), Tibbu (of Chad's Tibesti and Borku regions), Reguibat Legouacem (and other Mauritanian pastoralists), and Kababish (from Kordofan province in the central Sudan), dwell within the regions most affected by the present drought. Recent field work among pastoral nomads in eastern Libya (Johnson, 1973) also provides a perspective for an analysis of drought-related events.

Most of the available literature dealing with pastoral nomadism discusses average environmental conditions and the successful, traditional, long-term livelihood systems adapted to them. Departures from normalcy, and changes in nomadic culture and practice resulting from such outside inputs as improved breeding stock, veterinarian services, well-drilling programs, rangeland management efforts, and alternative labor opportunities, receive scant attention. The impact these inputs may have on the changing abilities of pastoral nomads to cope with drought have not been considered in any detail. Moreover, adequate data on response to previous droughts are largely unavailable. This statement cannot completely overcome such inadequacies in the available data. However, this paper has been prepared on the assumption that those engaged in the tasks of assistance should understand the traditional modes of response to and recovery from drought. Specifically, it has the following objectives:
(1) to delineate the characteristics of the nomadic mode of livelihood that condition a response to drought; (2) to develop a generalized

model of pastoral response to drought; and (3) to suggest in broad outline major developments likely to occur within the nomadic community in the absence of major external intervention when presently adverse environmental conditions relax.

Pastoral nomadism as a cultural-ecological adaptation

From a climatological perspective drought is an integral part of the variable climatic regime of the Sahel for it occurs somewhere in the zone each year. In the perception of the nomad drought prevails whenever the normal seasonal alternation of wet and dry conditions is changed by: (1) an extention of the dry season beyond its usual term; or (2) a persistence of moisture deficit conditions through a series of years. The nomadic response to drought is intimately linked to two basic characteristics that are an integral part of nomadic organizat on and operation. Mobility and access to a multiplicity of resources, together with a set of intertwined, mutually reinforcing cultural and ecological devices, permit and encourage survival in harsh environmental conditions. These devices primarily focus upon animal husbandry and make available resources which cannot be used in most other socio-economic contexts. Five essential features, ecological rationality, movement, use of different animal species, minimum herd numbers for family unit support, and dependence on agricultural commodities, underlie the pastoral nomadic adaptation.

Pastoral nomadism must be seen as a livelihood system that is a rational response to a moisture deficient, fragile environment. Dwelling in a region characterized by low water availability, seasonal drought, and widely scattered seasonal fodder resources, nomads make use of resources that are beyond the reach of settled agricultural

populations. The systems of movement developed by nomads to use available resources cope well with seasonal average conditions. Alternating concentration around dry season wells, or other permanent water sources, and movement to seasonal pasture in another part of the tribal territory, constitute the basis of the adaptation. In this system human population, herd size, and grazing and water resources are maintained in rough balance. While pastoral adaptations are capable of dealing with most of the environmental fluctuations around mean conditions, extreme events are always devastating. In the face of prolonged drought very serious losses of animals may occur. The impact of the extreme event has been complicated in recent years by two major inputs from outside the traditional system. On the one hand the introduction of sophisticated technology in the form of well-drilling programs and animal vaccinations has frequently encouraged the traditional nomadic tendency to overstock rangeland; catastrophic losses during severe drought years are often the result. At the other extreme, the wider awareness generated by modern communication media and the economic benefits available in new, non-traditional employment opportunities alter the general conditions supporting the nomadic adaptation and encourage a drift of nomads into alternative activities. Nonetheless, revolutionary developments of this type, while obviously crucial to an understanding of the present state of the nomadic life style, should not obscure the essential ecological rationality of the nomadic pastoral regime.

The crucial feature of this ecological rationality is the nomadic concentration upon animals as the primary basis of the subsistence economy. This emphasis upon a mobile animal capital

reflects the highly variable set of resources available to nomads. These resources of grass and water seldom occur in conjunction either temporally or spatially in amounts adequate to ensure the survival of a nomad's herds over a long period. Thus, movement in a regular seasonal cycle is essential to balance pasture and water availability. Yet, as is indicated in Table 1, the distances involved in such movement can be highly variable. Moreover, a generalized classification of this type represents mean conditions and obscures the departures caused by extrere events. Thus most Tuareg in the central Sahara move their subsistence animals no more than 80 km. (Bognon, 1962), a distance similar to the 76 km. average movement noted for Fulani (Hopen, 1958) in the better watered savanna, although long distance movement of up to 500 km. does occur to avoid seasonal drought. On the other hand, Sahelian Tuareg normally migrate more than 800 km. in a seasonal round before returning in the dry season to their home region, an eliptically shaped zone roughly 50 km. in length (Nicolas, 1947). Nonetheless, restricted

TABLE 1

TRIBE	LENGTH OF DISPLACEMENT (in a seasonal round)		
	SHORT (150 km.)	MEDIUM (150-375 km.)	LONG (375 km.)
Ahaggar Tuareg	X		
Sahel Tuareg			X
Reguibat			X
Sahel Mauritania		X	
Tibbu (Tibesti)	X		
Tibbu (Borku)		X	
Fulani	X		

movement for all or part of the year in corporately owned tribal territories, with small subregions being linked to specific lower-level genealogical segments (Peters, 1960; 1967), is the typical pattern; longer distance patterns of migration reflect either seasonal or long-term severe deficits.

In an attempt to maximize the amount of resources that can be utilized by a group as well as to ensure that some animals will survive an environmental disaster, different animal species are herded. These animal species, in turn, have disparate physiological characteristics, possess different potentialities as exploiters of vegetation, and have varying resistences to drought. While they are roughly distributed in a latitudinal fashion ranging from camels in the arid north to cattle in the more humid south, considerable interpenetration of the zones to which they are adapted occurs and a mix of animals in any one area is most common. Yet the differential ability of each species to exploit the environment means that they must be herded separately, thus placing considerable strain upon family and kin structures to provide the labor force required to manage the herd. In addition, there is a minimum number of animals that must be maintained in a family's herd in order to support a nomadic life style. That some nomadic families are constantly being lost to pastoral nomadic society (either temporarily or permanently) as a result of declining herd sizes and consequent enforced sedentarization is a well understood feature of the nomadic way of life. For sheep and goat herders fifty (Barth, 1964) to one hundred (Johnson, 1973) animals per family are generally required to maintain a nomadic way of life, while fifteen to twenty camels usually suffice in more arid districts.

Among cattle herders, such as the Fulani, minimum herd size requirements are not mentioned in the literature. The picture is complicated because many Fulani also farm and this serves to reduce the size of herd needed; however, at the same time most prefer milk as the staple food throughout the year which necessitates an increased herd size. Popen (1958, p. 64) suggests an average herd size of thirty cattle for his sample population, but this is suggestive rather than definitive. In exceptional cases, where nomadic peoples rely on caravan trading or other activities to provide subsistence needs, smaller herd sizes may suffice. But as a rule to fall below minimal requirements for any length of time entails at least temporary abandonment of the nomadic life style.

Just as movement is essential to the nomad's survival, so too is agriculture. While traditionally nomads are conceived of as hostile to the practice of agriculture, recent studies suggest that they often will engage directly in agricultural operations (R. Dyson-Hudson, 1972). Where intimate and direct involvement in agriculture does not take place, an exchange of goods between nomads and farmers in the Sahelian zone is traditional (Mazoudier, 1945; Dupire, 1962). Similarly, the date groves of desert oases form fixed points in the nomadic migration patterns and provide vitally important dietary contributions to the nomads of more arid areas (Cauneille, 1950; Dubie, 1953; Toupet, 1963). Although sanctified as an independent and superior way of life by its own ideology, pastoral nomadism represents an unbalanced, specialized life style, particularly in those situations where the production of agricultural commodities is in the hands of other livelihood groups. Since ethnic and economic specialization is the common

method of livelihood organization in West Africa (Horowitz, 1972) pastoral nomads find themselves partially hostage to a risk-prone natural environment and to a potentially hostile sedentary population controlling resources essential to nomadic survival.

Reaction to the Extreme Environmental Event

Pastoral nomadism constitutes an adjustment to an anticipated set of long-term environmental and social conditions. Yet experience suggests that such average environmental settings are seldom encountered in any one year and that fluctuations of variable duration around this average are most common. This is particularly true for the intermediate zones between desert and savanna, where the opportunities to develop a multiplicity of resources are greatest but where the possibilities of disaster are equally profound. The present drought conditions in West Africa, prolonged and far-reaching though they are, represent merely an extreme manifestation of the variability inherent in an arid environment. Indeed, there is evidence that the present drought was preceeded by a series of wetter than normal years in which surface pools of water remained in existence throughout the dry season (Bernus, 1966, pp. 7-8). Similarly, just as Tuareg from the central Sahara drift southward into Niger during dry periods, so too do cattle herders move northward during wet periods; the presence of Fulani and their cattle as far north as the Air Massif has been reported by Nicolaisen (Nicolaisen, 1963, p. 23) and indicates that the present drought was preceeded by an era of moister than normal conditions.

Drought is a natural mechanism which reduces overstocking of range land. This overstocking and overgrazing is a direct result of the nomad's initial response to the threat of drought. This

initial response to drought, occurring during periods when drought does not exist but when its threat is an ornipresent future risk coloring all activities, can be regarded as "normalcy" (Table 2) for a nomadic group and can be viewed as the initial stage in a scenario of nomadic response to moisture deficit. Knowing from experience that dry years will inevitably occur, the nomad attempts to cope with the

TABLE 2. Nomadic Response to Drought: A Scenario

STAGE	CHARACTERISTIC RESPONSE OF NOMAD
AVERAGE CONDITIONS	
A. Wet Season	Maximum resource use periods; herds increase, capital accumulates; rainy season occasionally extends into dry part of year.
B. Dry Season	Dry season restrictions on resources, especially water; seasonal water holes abandoned; pressure on weakest and most vulnerable animal species and individuals and on herders with limited capital; pressure on grazing resources near available water; no sale of animals.
ABNORMAL CONDITIONS	
I. Deepening Drought	Extension of dry conditions into normally moister period; shallow water holes abandoned - concentration on deep water sources, oases, etc. Serious pasture constraints; great pressure on animals and herders; limited movement; raiding, some animal sales.
II. Intense Drought	Decision to migrate to distant pastures must be made; massive "die-offs" of water-demanding species during migration; capital constraints, depletion of seed stock; ability to sell animals hindered by poor stock condition.
III. Total Prolonged Drought	+90% of all herd animals may be sold, slaughtered, or dead. Reserve capital stock (rugs, jewelry, etc.) depleted. Involuntary sedentarization; survival threatened.
IV. Recovery	Use of capital reserves (jewelry, rugs, slaves, etc.) and/or the sale of labor to rebuild herds.

risk of potential future environmental disaster by increasing his herd to the maximum extent possible during rainfall surplus years. Movement to rainfall areas within a traditional seasonal range is characteristic, although the specific zones grazed varies considerably from year to year (Johnson, 1969). Judicious herd management emphasizing a maximization of herd size and a restriction of capital expenditures is practiced during every rainy season in anticipation of some loss during the subsequent dry season. The potential for herd increase is substantial, and under constant favorable conditions forty fertile ewes will increase in the space of sixteen years to a flock of 2400 even with 15% of the flock being sent to market each spring (Naderi, 1971). The destructive implication for grassland quality of such unchecked growth is obvious. Drought exacerbates the normal seasonal cycle of herd increase and decline; it reduces the herd's expansion potential during the foreshortened rainy season, while whittling away the herd at an accelerated rate during the dry period.

Thus, prolonged drought acts as an impediment to long-term unlimited growth of herd size and brings herd numbers and pasture resources into rough balance. It is the drastic reduction in herd size resulting from extended drought that permits the recovery of over-utilized pastures and prepares a fragile ecosystem for the renewed expansion of the animal population that follows a return to more average conditions. Drought is not the only limiting factor, for animal diseases, of which the 1887-91 rinderpest epidemic reported by Hopen is a good example (Hopen, 1958, p. 16), can produce equally spectacular reductions in herd size.

During average conditions nomads experience drought seasonally when the dry season begins. The pressures represented by desiccating vegetation are experienced by nomads each year. In all cases the response is typical; seasonal water sources, usually surface pools of rainwater, are abandoned and the herds are shifted to the tribe's permanent watering points. As aridity increases, the need to water stock frequently increases pressure on both available water and pasture resources adjacent to wells and upon animals and herders themselves. The weakest and most vulnerable individuals and species may reach a mortality stresspoint and those herders with limited capital resources and minimal herd size experience particular pressure. For nomads existing at the margin of subsistence, normal seasonal pressures become too great, capital reserves and herd stocks fall too low, and involuntary sedentarization or employment as hired shepherds become the inevitable result.

Stage I in the nomadic response to drought occurs when moisture conditions fail to reappear with their expected seasonal regularity. Less reliable water sources are gradually abandoned and concentration on a restricted array of permanent deep-water wells take place (Prenaud and Pagot, 1962.) The result is to concentrate a larger number of animals and herders in increasingly restricted areas within tribal homelands. The situation becomes even more acute when the restricted movement focuses on agricultural areas; where such resources are in the hands of an <u>in situ</u> sedentary population, high rents for limited pasture and water are charged. Obligations to assist needy kin add another dimension to the struggle for access to scarce resources and gross overcrowding can take place. In one case in the Negev, 1200 sheep were pastured in 75 acres of rented land (Marx, 1962, p. 211).

Suprisingly, in conditions of deepening drought the pressure situation frequently encourages restricted movement rather than abrupt departures for distant areas. This inhibition against long-distance movement is often ascribed to "Islamic fatalism", but in fact is based on quite rational motives. Because nomads possess a detailed understanding of local pasture and water resources, there is a reluctance to move to zones where their local knowledge is less intimate (Nicolaisen, 1963, p. 131f). Not only are opportunities for access to resources external to the tribal territory only partially perceived, but also movement to alternative zones is invariably accompanied by high herd losses. Also there is fear that continuation of drought conditions may make a return to the tribal homeland difficult, if not impossible, for a considerable period of time.

Under these conditions, the concentration upon diminishing water supplies p aces increased pressure upon a reduced area of pasture. The ul imate result of this downward spiral, if drought continues, is the decimation or elimination of entire herds beginning with the weaker and less resistant individuals and species. At this time raiding to augment resources may take place. Traditionally nomads used the power potential inherent in their mobility to seize by force resources necessary for survival. Although raiding is an integral part of bedouin culture (Sweet, 1965), its operation is restricted today. The peace-keeping activities of colonial authorities and the contemporary acquisition of modern military technology by indigenous sedentary groups has changed the nomad-sedentary power balance and eliminated the possibility that nomads can take their requirements by force. From a position of dominance, the nomad has declined to the status of a beggar, a dependent on the charity of

settled folk for survival in conditions of extreme drought.

It is important to note that this process replicates the normal patterns and problems of concentration around permanent dry season water facilities (Asad, 1970), although in exacerbated form. As a consequence, the initial response of restricted mobility constitutes a short-term risk minimization policy predicated upon short-term departures from average conditions. The danger inherent in being caught in such a posture, should conditions prove more extreme than expected, is considerable. Trapped by widespread, prolonged drought, the nomad may be unable to shift to an alternative response and may be condemned to watch first his herd and then his kin die.

Given an expectation that severe drought will continue for a considerable period (Stage II), a decision to move herds and family to other, hopefully drought-free, areas may be taken. Generally, these movements are toward the edges of recognized tribal territory (Canneille, 1950) and it is usually at these times that conflict situations develop between pastoral groups for access to pasture. Movement of this type is usually in a direction and to a region that is familiar to the nomad, although its length and duration may be greater than the average seasonal cycle. As such, these movements represent a flexible response to the variability inherent in the nomad's habitat (Johnson, 1969), and are usually made to areas with which the nomad has experience. Herds may be split with the more vulnerable species moved to new locations in the expectation that their survivability may be enhanced, while durable subsistence animals remain behind. This is particularly true for nomads who herd a number of animal species, often in widely dispersed areas. Alternatively, migration of entire tribal components may take place. Under extreme

conditions, albeit with great reluctance, the Ahagger Tuareg, for example, move their household goat herds as much as 500 km. to join their camel herds which usually reside in the Tamesna region of Niger (Rognon, 1963). An equally common practice among nomads either practicing agriculture or returning to an oasis at some fixed point in their migration cycle is to move to the agricultural area and hope to wait out adverse conditions (Canneille, 1950) near permanent water sources. This may avoid complications with other nomadic tribes but it is certain to cause difficulties with the local agricultural population.

When all else fails, the nomad abandons his life style, at least temporarily (Stage III). Surviving stock may be sold, if a market can be found, or slaughtered for domestic consumption. Attempts to sell animals during this period are hampered by the poor condition of the livestock and the financial returns of such sales never approach the value of the animals under normal circumstances. Loss of stock frequently exceeds 90% (Hopen, 1958; Johnson, 1973), the descent to poverty is abrupt, and the rate of recovery slow, arduous, and uncertain. Rugs, jewelry, and other hoarded capital resources are expended only with great reluctance, and alternative employment sought, in an attempt to preserve enough capital to permit purchase of animals and rebuilding of herds when conditions change.

This process of sedentarization is always viewed as a temporary expedient, but it is essential to realize that it is an integral part of nomadic society. Rich and poor are continuously sloughed off from nomadic society (Barth, 1964; Stenning, 1957, 1959). While many wealthy nomads may visualize settlement on or

near property purchased with the proceeds of their herds as permanent, among the poor the expectation is that nomadic life will be resumed as soon as capital and environmental conditions permit. Again, prolonged drought may exacerbate, accelerate, and in some cases make permanent, normal tendencies, but it represents a difference in degree rather than in kind.

Post-Drought Recovery

Once environmental conditions ameliorate, there is every reason to assume, except in those areas where settlement has become permanent, that nomads will want to resume their former way of life. In 1914, at the end of the last Sahel-wide drought and before the full effects of European colonial intervention upon indigenous systems became apparent, traditional patterns of recovery, now only vaguely understood and remembered, would have taken place. Today pastoral nomadism has been placed under very considerable stress as a result of changing socio-economic conditions. These stresses constrain the ability of a life style already under pressure to generate recovery from drought by means of its own resources. Indeed, the planning initiatives of central governments are likely to encourage settlement of the drought-impoverished nomadic community south of its traditional areas in regions deemed more stable and less prone to environmental risk. It is likely that such policies will conflict with existing pastoral desires and result in the occurrence of a conflict situation when the normal recovery drives inherent in pastoral nomadism begin to operate.

The first and most powerful recovery drive will be the desire to resume pastoral migrations. However, since most

nomadic stock will have been destroyed by the drought, and since for many nomads available capital reserves will have been drastically depleted, only a limited number of pastoralists will be able to resume a nomadic life style based on their own resources. This will create demands for governmental assistance. These pressures for assistance should be heeded, but the approach should be a cautious one. Overly rapid restocking must be avoided; the emphasis should be on introducing higher quality stock with a tolerance of local conditions equal or superior to that of the lost populations. Despite anticipatable nomadic pressure for rapid expansion of herd size, sufficient time for pasture regeneration, as would occur during the slow herd rebuilding process characteristic of the traditional nomadic regime, should be permitted. Similarly, excessively zealous expansion of watering facilities as a hedge against anticipated future droughts should be avoided until rangeland regeneration and adequate assessment of long-term support capacity has taken place. Otherwise too rapid response to the nomad's demands for recovery assistance may well result in permanent degradation of the area. Grass conditions not water needs should be the major determinant supplies.

A corollary of the desire to resume migration is the expectable attempt to return to home territories on the part of those nomads who are capable of doing so. The pressure to do so will be intense. All groups forced by the drought to migrate outside their traditional range will be existing in those areas on sufferance. The long-term right to use those resources will be vested in other groups. Thus the pull of home territories, indis-

putably their possession, plus the push of other corporate bodies, be they nomadic or agricultural, should generate great pressures for a return to familiar territories. This impulse should be encouraged. For not only do nomads know the resources of their own areas in painstaking detail, but also there is little likelihood of other groups being able to or desirous of using those resources. Thus the use of marginal resources by a mobile pastoral life style enhances overall economic productivity. Permanent collapse of pastoral nomadism may well mean a reduction in the quantity of animal products available, a loss of resource base undesirable in countries striving to generate economic growth. Although it can be argued that the nomad's reluctance to sell his stock reduces his importance to economic development and capital formation, modest structural rearrangements in tax policy and collection efficiency can be utilized to enhance pastoralism's contribution to national goals. The death of a way of life by either neglect or conscious policy precludes this possibility.

The recovery period is also likely to be characterized by considerable social unrest which will increase in severity in proportion to the length of the drought. Many of these strains will be present within the nomadic milieu itself. Because the wealthiest members of nomadic society have the largest herds, their chances of retaining some stock are enhanced. This gives them a decided advantage when recovery becomes possible. Those individuals with either capital or stock will find themselves in a powerful position and the extent of their control over the behavior of their fellow tribesmen will be extended. Under normal circumstances ties of kinship and marriage are activated to enable an individual to derive

assistance from within one's corporate group. During extremely widespread catastrophic events this help may no longer be available. The result may be a setting of hostility and tension within the nomadic community as traditional relationships degenerate and new, and perhaps undesirably counter-productive, patterns of obligation, debt, and clientship emerge.

Just as tensions are likely to develop within nomadic society, so too is hostility toward local governments possible. Pastoral nomads have always required support from agricultural society in order to remain viable. In the past, this assistance could be extracted by force, but today government sponsored agricultural expansion has removed many former pasture areas from use for animal husbandry while modern military technology has conferred decisive advantages upon sedentary society. Restricted to the most marginal areas agriculturally, nomadism occupies an increasingly fragile and delicate position. The consequences of drought are exacerbated by the increasingly tenuous resource base remaining available for exploitation. This pressure situation is ideally suited to the generation of anti-governmental feelings. In many cases, these are intensified by ethnic differences. Governmental support is usually drawn from the sedentary portion of the population, and pressure from the nomadic community for assistance is likely to be drowned by the demands of agriculturalists for priority in the allocation of scarce aid resources. In many instances traditional hostility between nomad and farmer (although frequently overemphasized) has already resulted in active hostilities, and in these situations relief for nomads will

be ignored or actively discouraged. Generally, the consequence of such circumstances will be the demise of the nomad and his unwilling stabilization in place or his search for new opportunities elsewhere.

Given that pastoral nomadism is an ecologically rational resource use system, there are a number of focal points in the system where limited amounts of aid would enhance the overall efficiency of pastoralism and speed its long-term recovery. Attention should be paid to selectively introducing modern technology into the migration cycle. Increased use of trucks to shift herders and their animals to wet season pasture would insure that distant forage resources could be reached quickly and efficiently. Possession of trucks would also insure that herds could be moved rapidly away from water-deficient areas with only minimal loss as well as improve the ease of reaching market centers. Considerable steps in this direction have occured in Libya without government sponsorship since the discovery of oil. It is not difficult to envision the Land Rover or Jeep replacing the camel in tribal migration, while short wave radio communications between trucks and a central base improve traditional information distribution systems that bring herds, grass, and water into contact.

Sedentarized ranching in particularly favorable regions might be a solution. Although this fails to make creative use of the special genius of nomadism, its use of mobility to reach otherwise inaccessible resources, it does salvage stockraising skills that would be lost if a shift to other occupations or migration to urban areas became the dominant feature of the recovery period. More suitable would be the provision of guarantees to the nomadic community that would serve to protect it against the risk of future

drought. Since lack of pasture is as likely to cause animal mortality as is the absence of water, the stockpiling of animal fodder in the dry season areas of the tribal homeland is probably more important than the drilling of new well facilities. Increased specialization on particular animal species would improve efficiency. Rather than having to herd a number of different animals as a hedge against drought, concentration of effort on the most productive species seems desirable. However, this would require a willingness on the part of local governments to provide firm guarantees of insurance capital to enable recovery to take place if disaster should strike.

Similarly, the nomad's tendency to increase herds to the maximum size possible could be controlled by a judicious combination of taxation designed to encourage the sale of animals to preserve rangeland management balance plus guarantees that smaller herd sizes would not place the nomad in an untenable long-term position. Finally, more specialized nomadic livestock operations that reduce the diversity of the subsistence economy will increase the nomad's dependence on the sedentary community for agricultural goods and may make special provisions necessary.

Admittedly many of these suggestions for possible adaptive response by and redirection of pastoral nomadism would be difficult to attain. The spontaneous integration of the Land Rover into the pastoral culture of eastern Libya is an extraordinary response to the abrupt discovery and rapid development of an unusually rich fossil fuel resource. Given the limited prospects for sudden infusions of locally generated capital in the impoverished Sahelian states, the broad-scale application of technological fixes is un-

likely. On the other hand, the use of relatively simple taxation devices to encourage the sale of herd animals has been employed successfully in the Sudan; good results in terms of generating capital to meet national goals and reducing overgrazing problems have been reported and these techniques could be extended to other areas. However, one of the major issues in assisting the recovery effort remains the difficult task of identifying those critical foci where limited investments will yield maximum improvements at the grass roots level.

In the absence of palliative short-term relief assistance and of creative programs for long-term adaptation, the prospect for nomadic recovery following the end of the present drought is not good. With herds destroyed, capital depleted and normal internal patters of self-help inoperative, the conditions for the long-term survival of pastoral nomadism are lacking. Already under great stress as a result of changing political, cultural, and social arrangements, pastoral nomadism may well be dealt a coup de grace by the present drought. In the absence of intervention, reconstitution of the nomadic way of life by all but a remnant is unlikely. The result will be the loss of a marginal ecological niche that can only be exploited by a pastoral way of life.

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METEOROLOGICAL AND HYDROLOGICAL SERVICES

Special Sahelian Office

74-00368

1. The problem

The climate of the six Sahelian countries of West Africa, lying approximately between latitudes 10 and 20° N, is semi-arid generally and subject to catastrophic droughts sometimes covering a few successive years. The zone is marginal for production of food and water for an increasing population, estimated at 25 million in 1972, of which nearly 90% are engaged in agriculture. With low rainfall during a short season and high potential evapotranspiration, the ecological system is very fragile. During drought years the imbalance between nature's provisions and the increasing demands of man and his animals results in southwards encroachment of the desert which is difficult to arrest and may be impossible to reverse.

Of the total area of 5.3 million square kilometres, only 27% receive an average annual rainfall in excess of the 500 mm which must be regarded as the lower limit to support a permanent system of rainfed agriculture in that region. About 20 per cent of the total area is too marginal for rain-fed crop cultivation but is partly suitable for migratory livestock herding. Over 50% of the region is desert.

There are proposals to triple the small areas already under irrigated or flood-retreat cultivation in the large river basins but these would still amount to only a small fraction of the total land surface. Moreover production from irrigated areas, although less closely correlated with distribution of rainfall than that from rain-fed crops, will remain dependent upon the vagaries of weather over the river catchment areas further south.

The whole of the Sahelian zone has two very distinct seasons associated with the annual migration of the Intertropical Convergence Zone (ITCZ). The longer season, from September to April, when the ITCZ is to the south, is almost completely dry with nearly cloudless skies and the north-easterly Harmattan from desert regions causing high potential evapotranspiration of about 1600 mm during this season.

During the normal rain season from May to August the moisture-bearing south-westerly winds from the South Atlantic Ocean and the Congo Basin push the ITCZ over the Sahelian zone to its more northerly positions near the Tropic of Cancer in late July and early August. The instability just to the south of the ITCZ gives the rains on which the economy of the zone almost entirely depends.

The timing, intensity and duration of the ITCZ over any part of the zone determine the quality, quantity and length of the rains and the success of the crop cycles. The isolines of mean annual rainfall totals of the region, as shown on figure I at the end of this review, therefore lie almost along lines of latitude, as does the ITCZ, and show a steep rainfall gradient from north to south.

At the frontier of the Saharan desert, the northern parts of the Sahel receive 100 to 400 mm of rain in an average year. This area has for many centuries supported migratory herding of camels, sheep, goats and cattle on sparse xerophytic shrubs and grasses with very few trees, mainly palms and acacias. The Sudanian zone, only a few hundred kilometres nearer the equator, has average annual rainfall of 800 to 1,000 mm and supports sedentary farming of millet, sorghum maize, peas and pulses, groundnuts and cotton.

The well known irregularities in the movements and intensities of the ITCZ from year to year result not only in high variability of total amounts of rainfall but also in the length of the season of crop growth. The isolines of rainfall in 1973, expressed on the lower half of figure I as percentages of the long-period means, indicate that 1973 was again a very dry year over the zone as a whole. The approximate latitudinal alignment of these isolines of percentage in 1973 and the gradient from north to south again reflect the influence of the ITCZ and demonstrate that in drought years it is the northern zones which suffer greater departures from average weather.

Figure II shows the seasonal distribution of rainfall amounts in each 10-day period over 30 years for two stations in Mali - Mopti on the edge of the Sahelian zone (annual total 530 mm) and Bamako in the southern Sudanian zone (1068 mm). The diagrams of values exceeded in 20% and in 80% of all years emphasize the high variability over the years of both rainfall amounts and of length of rain seasons at both stations but especially in the Sahelian zone.

Such climatic conditions result in numerous problems in selection of varieties and species of crops, in adaptation of all husbandry practices and in management generally. Similarly the problems in hydrology and water management, such as those in the supply of water for crop irrigation and for migratory herds as well as for development of transport on rivers and lakes, are a reflection of the shortage and irregularity of rainfall.

Solar energy, which is abundant, and wind energy could apparently be harnessed throughout the Sahelian zone. These sources are virtually unused whilst mineral oil products have to be imported and distributed at great cost and trees are destroyed to supply domestic firewood with the resultant degradation of the environment.

2. Significance of the meteorological and hydrological services sector to the economy and its relationship to other economic sectors

Shortage and irregularity of rain being at the root of problems of the six Sahelian countries, successful development in other sectors must depend upon information from the meteorological and hydrological services sectors.

One of the first problems which comes to mind is the potential in artificial augmentation of rainfall, for any increase in rainfall which could be obtained in this way would clearly be beneficial. Some attempts have already been made to promote increases by cloud seeding but the ways in which operations were carried out make it extremely difficult to assess the results.

There is at present only a remote possibility that weather can be modified to prevent drought. The contribution that meteorological and hydrological services can make towards mitigation of the effects of drought and towards economic development are, however, large. There are two main aspects of the dependence of other sectors on meteorological and hydrological

knowledge. On the one hand pre-investment studies for all development plans require a knowledge of climatic and hydrological factors more complete and in greater detail than is at present available. On the other hand, efficient management in almost all sectors requires forecasting, both climatological forecasting for the longer-term and synoptic weather forecasting in the short-term, which is not available generally to sectors other than aviation. Hydrological forecasting, already initiated within a UNDP/WMO Project in Mali and Guinea will prove of considerable importance for management of water resources.

Without measurement and understanding of weather factors, attempts to develop production, by extension or intensification in normal as well as in dry years, and at the same time to preserve the fragile ecological system of the environment, can only be on a trial and error basis. Such a basis can be costly, time-consuming and possibly disastrous.

It could not be over emphasized that all investment projects dealing with water resources (be it in agriculture, industry, hydropower and water supply) cannot be rationally and economically planned and executed without meteorological and hydrological data resulting from time-series, requiring at least several years of continuous observation in a rationally designed network of meterological and hydrological stations.

Studies of weather/crop correlations are urgently required to improve the early warning of crop failure which is essential for effective preparation of relief of food shortages for men and animals. Also within the agricultural sector, such problems as land utilization, introduction of new varieties and species, modification of husbandry practices and new methods of pasture management all require detailed maps of climatic conditions. These maps should define probabilities of rainfall amounts and timing, vapotranspiration, wind, temperature and radiation for specific areas.

Management of water resources and development of water supplies require similar maps, run-off, river flow and lake level information and estimation of ground water recharge. Hydrological studies involving the close relationship between certain meteorological and hydrological data such as rainfall and runoff and also other relevant hydrological characteristics are necessary for the further planning of investment projects and the optimum use of surface water resources.

Since distribution of disease vectors and pests is largely a function of climatic factors an improvement of knowledge in this sector is necessary in consideration of human, animal and plant health.

Many parts of the industrial, transport and trade sectors will also depend upon climatological and hydrological considerations, especially at the feasibility study stage. Studies on the supply of energy must include examination of the potential uses of solar and wind energy.

The above remarks indicate the urgent necessity for meteorological investigations of past data in pre-investment studies for other sectors. Also forecasts of weather conditions and water supplies will be necessary for efficient operation of most installations and agricultural enterprises.

Short term forecasts are required for many purposes in agriculture. For example preparation of seed beds and sowing of seeds should be determined by forecasts of rain. At present seeds are sown repeatedly, and often uselessly, as from a chosen calendar date until sufficient rain falls to permit successful germination and growth. Use of herbicides and pesticides is successful only if application is followed by favourable weather conditions.

Longer term weather forecasts are required for planning of agricultural operations and pasture control, for forecasting river and lake levels which determine operations in flood-irrigated areas and transportation by water.

3. Achievements in the past

The achievements in the meteorological sector may be considered from three aspects - the climatological data, investigations and forecasting. Development of meteorology in the Sahelian zone has, from all three aspects, been mainly towards the provision of services for aviation and for the regional aspects of the Global Observing System and the Global Telecommunication System of the World Weather Watch.

A network of stations making vertical soundings of the atmosphere has been established and with few additions would be sufficient for upper air meteorology. Data available have been summarized and published. Stations for direct reception of photographs from meteorological satellites have been established in recent years in capitals of three of the six countries but are required also in the other three. The satellite data for the region which have been accumulated over recent years are summarized in NOAA publications.

Climatological data for the 64 synoptic stations in the six countries have been published in summary form over a sufficient number of years to provide 10- and 20-year monthly means of the elements observed for synoptic purposes. The density of this network, averaging one station per 100,000 square kilometres approximately, is however too sparse to provide climatological maps for application to the economy generally.

Relatively few agro-meteorological, climatological and rainfall stations have been established. Detailed observations are stored in the original form in the archives of national services and intergovernmental agencies. Simple summaries have been published in various documents on an increasing scale during recent years. The most centralized sources of published data other than rainfall are the monthly publication of Asecna covering the years 1953 to 1972 and the year books of other agencies. Special mention must be made of the valuable co-operation between Governments, CIEH, ORSTOM and Asecna[1] in collections of daily rainfall data available in the zone and their transfer to punched cards. Publication of these data up to 1965 is expected to be completed for the six Sahelian countries by 1974 and is expected to continue in subsequent years. Publication of data at the national level is developing steadily.

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1) CIEH - Comité Interafricain d'Etudes Hydrauliques, ORSTOM - Office de la Recherches Scientifique et Technique Outre Mer and ASECNA - Agence pour la Securité de la Navigation Aèrienne en Afrique et à Madagascar.

Some hydrological data are also being published at the national level by national services and CIEH and ORSTOM are covering the zone as a whole. Other hydrological publications are available and include ORSTOM mongraphs on the Senegal, Niger, Chari and Lagone rivers and the Unesco monograph on Lake Chad. Three international river commissions have been formed over the last ten years for the development of three large river basins in the region namely the Senegal, the Niger and the Lagone. The work performed by these commissions, though limited and study-oriented, permitted the collection and exchange of useful data and information among the countries concerned.

A few investigations into synoptic meteorology, agro-meteorology, hydro-meteorology and climatology have been made on the basis of the rather sparse data of past years by various agencies. Most of these have been carried out for individual stations and there is a lack of meteorological information on the zone as a whole. Mention may, however, be made of the agro-climatology survey carried out by the FAO/Unesco/WMO Interagency Group in 1963-1967 of which results were published in full in a Technical Report by FAO and in a shortened version as Technical Note No. 86 by WMO[2]. Another valuable contribution to the knowledge of the region as a whole is the series of monthly maps of potential evapotranspiration established by CIEH and published in 1972.

Increased effort has been made during the recent drought years by national services and other agencies to meet the needs for rapid collection and publication of rainfall data in the form of tables, histograms and simple national or regional maps which are necessary for drought monitoring in many sectors of the economy.

Short-term forecasting is carried out in the Regional Meteorological Centre at Dakar and in the six national Meteorological Centres for aviation according to the standards set by WMO and ICAO regulations. The provision of daily forecasts for other sectors of the economy and for the public is limited and variable over the six countries. There is however a new awareness of the need to improve short-term forecasts for special purposes, especially for agriculture.

Attempts have been made by several agencies to analyse the past rainfall data with a view to obtaining indications for forecasting over longer periods, from a week ahead to years ahead but there has been little convincing success in determining any long-term trends or cycles in rainfall amounts over past years.

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2) This survey was followed up by a Technical Conference (Dakar 1971), the proceedings of which were published in WMO Publication No. 340.

4. Objectives and targets for the future

The aims in the meteorological and hydrological services programme for the six Sahelian countries may be divided into three groups. Firstly, investigations on the basis of existing data are urgently required for pre-investment studies in almost all sectors of the economy. Secondly, in the longer-term, it is necessary to restructure the meteorological services Networks of stations to provide observations for all purposes should be established. Local personnel should be trained for processing these observations and interpreting them into summaries, analyses and forecasts for application in all sectors during future years. Thirdly, the study of potentialities in the artificial augmentation of rainfall merits serious consideration.

As regards the investigations using existing data, four problem areas have been identified. The first of these is the urgent necessity to establish weather/crop correlations to improve the early warning system of crop failure. This early warning system is designed to assist provision of food and establishment of other emergency plans to mitigate the catastrophic effects of drought years. A useful monitoring of rainfall has been carried out by the World Food Programme and other agencies through 1973 but the aim must be to interpret weather data into an assessment of future food production. This can only be done if weather/crop correlations are established. The studies in this field should be carried out during the first half of 1974 and extended over a period of testing during the rain season May to August 1974.

The other three fields of investigation are designed essentially to provide meteorological and hydrological analyses for the many pre-investment studies which will be necessary in other sectors of the economy during the next year or two. They will however also be of permanent value in all later development projects as well as in the operational activities in all sectors.

Details of these three fields of investigations are given in the following section listing and describing all projects. On the one hand they consist of meteorological and hydrological studies involving the establishment of weather/water runoff correlations, surface water mapping and maps of agricultural and water resources potential. These preinvestment studies are a prerequisite for the development and regulation of the many drainage systems which cover a substantial portion of the area of the region and which include many major rivers : the Senegal, the Niger, the Volta, the Lagone, the Komadougou and the Chari rivers. Such studies are also necessary for the formulation of short and long-term prevention measures which should be taken to alleviate the effects of droughts and for the resolution of some important policy issues regarding the use of the international rivers in the region.

On the other hand they will include two separate approaches to longer period forecasting through statistical studies of past data and through investigations into cause and effect of the changing pattern of the global circulation of the atmosphere.

The next group of objectives are for the longer term assistance of meteorological and hydrological services to promotion of economic growth in general and to mitigation of the effects of drought. In periods of favourable as well as unfavourable weather it is generally agreed, since the success or failure of man's activities are determined by nature's provisions, that meteorological knowledge is necessary to promote man's well-being. In the six Sahelian countries it is particularly necessary that meteorological knowledge should be raised to the standards achieved in most parts of the world. The objectives must be to restructure and expand meteorological and hydrological services so that they may in future provide the necessary assistance to all sectors of the economy. Particular emphasis must be placed on application of meteorology to agricultural production for increasing populations and to protection of the environment in drought periods when weather tips the delicate balance against vegetation and towards further encroachment of the desert.

This objective requires the establishment of well-planned networks of stations for agro-meteorology, hydro-meteorology, climatology and hydrology, as well as for aeronautical meteorology. These networks must provide observations over the territories as a whole wherever man may live as well as in the better-watered Sudanian zone where activity has been concentrated in the past.

The interpretation of these observations for application in all economic sectors requires an adequate establishment of fully-trained African meteorologists and hydrologists and buildings and equipment for centralized meteorological and hydrological services. In the interests of economy and efficiency these services should be established at two levels - the national and regional levels.

Finally, the potentialities in the artificial augmentation of rainfall must be examined. The first objective must be conclusions on the possibilities of increasing rainfall, especially in dry years and identification of problems which may arise in practice. Also, in view of the high cost of operations, a cost/benefit analysis must be attempted. The design of such studies is being examined but no specific proposals are made at this stage.

5. Potential projects

Projects to meet the objectives in pre-investment studies on existing data and in the restructuring of national meteorological and related hydrological services are listed below. The investment figures indicated are not based on detailed surveys in all cases and give an order of magnitude until further study permits elaboration of the proposals.

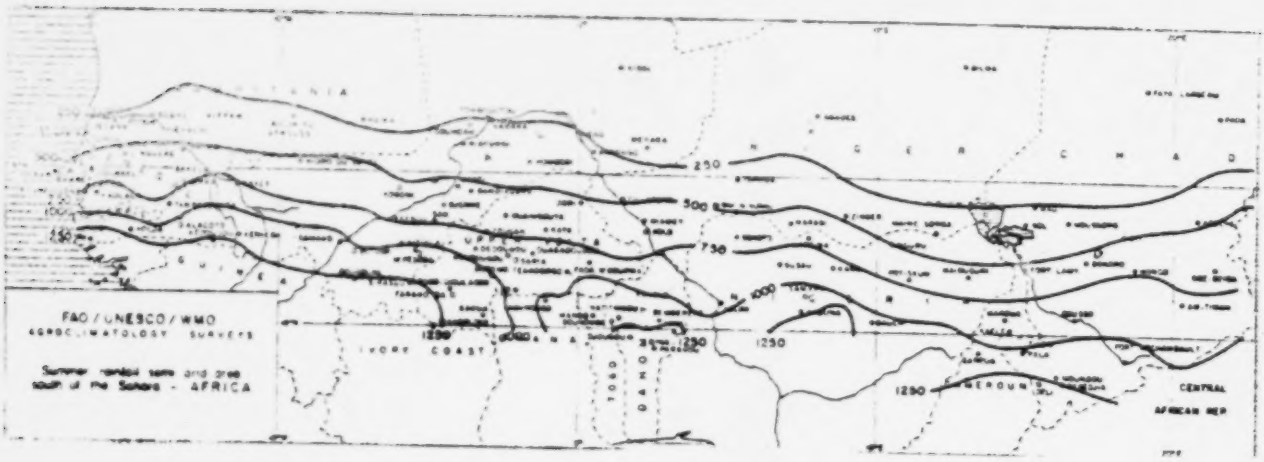
Further detail and breakdown of the costs of the projects are given in Appendices A and B.

Project I - Studies	Investment U.S. $ 1,000
Establishment of crop/weather correlations to improve the early warning system	50
Establishment of weather/run-off correlations and maps of agricultural and water resources potential	70
Further studies of possible trends and persistence and periodic recurrence of characteristics in monthly and annual rainfall	10
Studies of droughts in tropical and sub-tropical belts with particular reference to the Sudano-Sahelian zone and the general atmospheric circulation	30
	160
Project II - Restructuring of Meteorological and Hydrological Services	
Improvement and expansion of national services	
Creation of Sudano-Sahelian Hydrometeorological Centre and Regional Training School	
	6,700

FIGURE I

Rainfall of the Sudano-Sahelian zone of West Africa

Mean annual isohyets



Isolin s of 1973 rainfall expressed as a percentage of the means

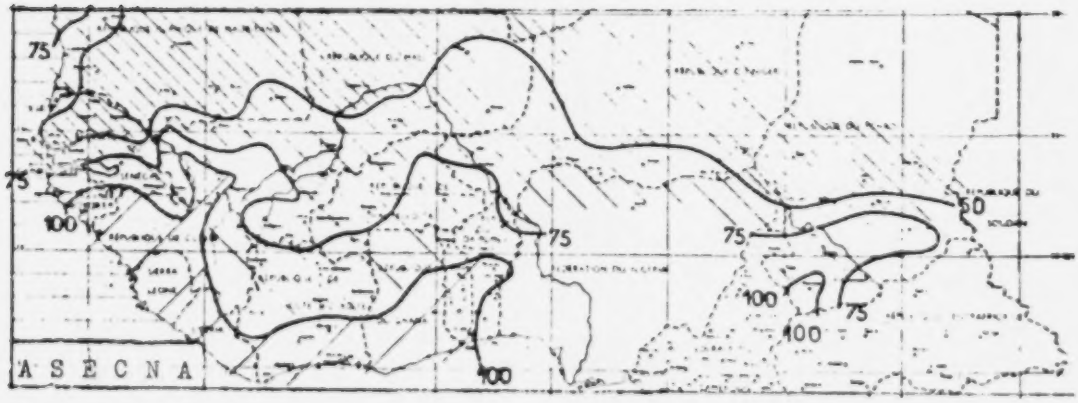
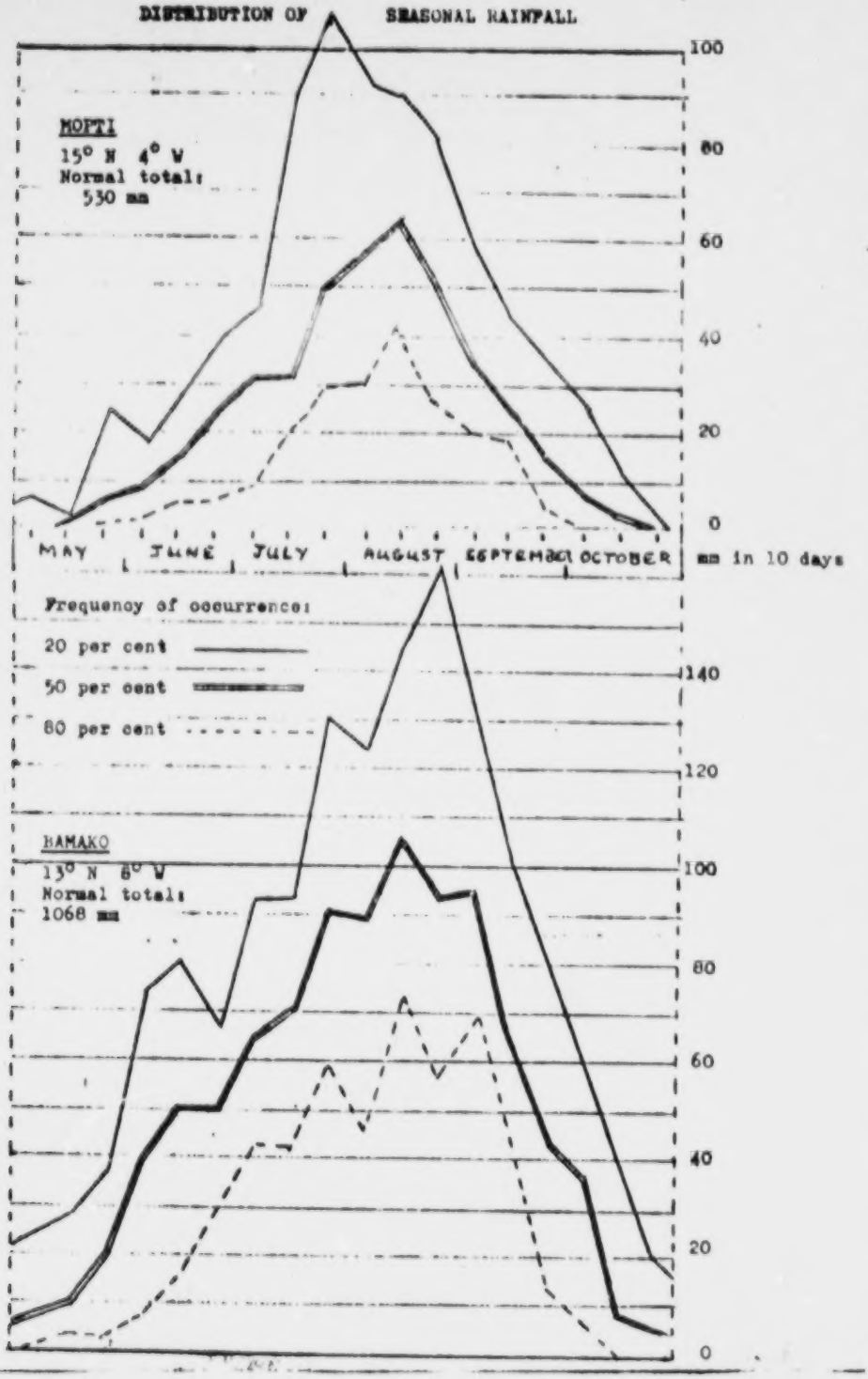


FIGURE II

DISTRIBUTION OF SEASONAL RAINFALL



Project I - Studies

1. Establishment of crop/weather correlations

Objective

Improvement of early warning system for crop failure and of general planning of food supplies and commercial crops during each year. Completion by August 1974.

External input — U.S. $ 1,000

Expert services - two for 6 months
- one agrometeorologist, one agronomist

12 man months	30
Travel and miscellaneous	20
	50

Description

Collections of data on some weather elements and production of some crops in past years have already been made. Additional information is available in the Sudano-Sahelian countries and research agencies. Correlations of these crop/weather data, such as have successfully been made in other countries, would help to improve planning for 1974/75 and future years.

2. Establishment of weather/run-off correlations and compilation of maps of agricultural and water resources potentials

Objective

Provision of pre-investment knowledge for projects in development of water resources and agriculture.

External input

Expert services - three for six months
- one agrometeorologist, one agronomist and one hydrologist

	U.S. $ 1,000
18 man months	45
Travel, publications and miscellaneous	25
	70

Description

The balance between natural factors and between man and nature in the fragile eco-system of the Sudano-Sahelian countries is very delicate. Projects for development of water resources, agriculture and protection of the soil and its vegetation cover can only be well founded at the outset if they are based on knowledge of meteorological and hydrological factors.

In definition of policies for development and management of forestry and fishing and of sedentary agriculture and nomadic herding, the most frequent problems are selection of areas, of species and varieties and of husbandry methods. These selections necessarily depend upon weather factors. Similarly development and management of water resources must be determined after assessments of river flows and recharge of surface and underground water reservoirs which also largely depend upon rainfall and evapotranspiration.

The time factor involved in successful assessment of water run-off or of appropriate periods at which to sow seeds may be no more than 24 hours. Pasture production and germination and flower fertilization in cultivated crops are determined by weather over periods no longer than five to ten days. In the Sudano-Sahelian zone a healthy, well established, plantation of sorghum, millet or maize may produce almost nothing at harvest if a dry period of ten to fifteen days arrests plant growth or grain development.

Different varieties of crops have different lengths of cycle from germination to maturity so that successful production depends upon the length of the period of useful rains which is highly variable over the zone both in space and in time. It is not infrequent in the Sudano-Sahelian zone that seeds are repeatedly sown, as many as four or more times, before soil moisture is adequate for establishment of young plants. Sowing so late in the season that there is no reasonable hope of completion of the crop cycle beforedesiccating weather sets in is also reported.

Most of the climatological studies already made, including the FAO/Unesco/WMO Agrometeorological Survey made over the zone in 1963-67, have been mainly on data averaged over periods of a month and simple monthly averages have been derived over periods of years. Such investigations as have been made into the effects of weather over short periods on crop production have been applicable to particular varieties at isolated stations, mainly near the large river basins, and insufficiently comprehensive.

Development of agricultural production and water resources over the Sudano-Sahelian zone as a whole requires analysis of weather factors over short periods and the compilations of maps showing, for each identifiable area and for each of the more important crops, the beginning and end of the season of weather suitable for the crop cycle and regularity of the weather during the season.

In defining areas suitable for different crops a failure rate of 20% of all years is considered acceptable. The apparent complexity of the task of preparing maps will necessarily be reduced by concentration on rainfall data in the absence in many areas of comprehensive observations of evapotranspiration or wind, radiation and air temperatures and humidity.

These studies are closely connected with that of crop/weather correlations and are separated therefrom only because of the extreme urgency of improving the early warning system before possible crop failure during the next rain season.

It is recommended that the whole of these studies should be regarded as a follow-up of the Agroclimatological Survey of a Semi-arid Area in Africa South of the Sahara which was carried out in 1963-1967 as an FAO/Unesco/WMO Interagency project. Results of this survey were published in full in a Technical Report by FAO and in a shortened version as Technical Note No. 86 by WMO.

3. Further studies of trends and of persistence and periodic recurrence of characteristics of monthly and annual rainfall

Objective

Determination of probabilities of characteristics of future rain seasons with particular reference to:

(i) total amount of rainfall;

(ii) beginning, end and length of season of useful rains.

External input — U.S. $ 1,000

Expert services - one statistical climatologist

4 man months — 10

Description

Efficient planning in every sector of the socio-economic structure would be aided by a knowledge of statistical probability of future climatic factors in the long-term, in the years immediately ahead or in the remainder of a rain season.

Various investigators have searched for trends and cycles of rainfall. Convincing evidence has not yet been found either of long-term trends or cycles sufficient to give guidance for the future. But previous studies have mostly been on total annual rainfall data from individual stations which may not have been statistically representative of large areas. The fundamental importance of even approximate forecasts for future years, seasons or parts of seasons justifies further statistical investigations based on monthly and annual rainfall averaged over latitudinal sub-zones and on river flows and lake levels.

4. Studies of droughts in tropical and sub-tropical belts with particular reference to the Sudano-Sahelian zone and the general atmospheric circulation

Objective

Provision of long-term forecasts derived from correlations of weather fluctuations in the Sudano-Sahelian zone with preceding weather factors over other areas of the globe.

External input	U.S. $ 1,000
Expert services - two for six months - one synoptic meteorologist - one dynamic climatologist	
12 man months	25
Miscellaneous	5
	30

Description

Indications of future climatic factors a season or even only ten days ahead would greatly aid planning in agriculture and water resources over the shorter term.

Certainly the amount of rainfall and the length of the rain season in the Sudano-Sahelian zone are functions of the intensity and movements of the Inter-tropical Convergence Zone (ITCZ) in the northern part of its annual migration during the period from May to September. The intensity and movements of the ITCZ are mainly dependent upon those of the semi-permanent anticyclones centred in the regions of the Azores, St. Helena and Libya. Studies of the changing characteristics of these anticyclones in relation to rainfall in the Sudano-Sahelian sub-zones might show up correlations which would have value for prognosis of rainfall a few days or for longer periods ahead.

Nevertheless there is much evidence that the phenomenon of seasonal and monthly rainfall deficits over large belts is global and not peculiar to the semi-arid area to the south of the Sahara. In 1972 the drought extended in a belt between latitudes 10° and 20°N from America through Africa to Asia; many other areas in southern Africa and other parts of the world also had relatively large rainfall deficits.

The causes of large-scale drought may be expressed in terms of abnormalities in the general circulation of the atmosphere and in the intensity and position of the major belts of high and low atmospheric pressure. But there is poor understanding of the causes of these abnormalities, which have been attributed to sunspots, volcanic dust or other pollution of the atmosphere and, more recently, to oil pollution of the ocean surfaces. Whatever may be the causes, there is much potential value in searches for correlation between rainfall and the abnormalities of the general circulation for some of these correlations could have value in longer-period forecasting.

Several studies have already been made in this field but it is recommended that special effort now be made to correlate the large variations of seasonal rainfall in many tropical and sub-tropical belts of the world with abnormalities of the atmospheric circulation systems. The Sudano-Sahelian zone now deserves a special attention in such studies which could eventually be extended to other areas subject to large-scale drought.

Project II - Development of Meteorological and Hydrological Services in the Sudano-Sahelian zone

Objectives

Development of meteorological organization capable of providing service to all sectors of the economy in the Sudano-Sahelian zone as a whole and in individual countries.

This project consists of two inter-dependent parts:

A. Improvement and expansion of National Meteorological and Hydrological Services in each of the six Sudano-Sahelian countries providing:

(i) adequate data from planned networks of stations making routine observations for all meteorological and hydrological purposes;

(ii) collection and verification of all data and storage in national archives;

(iii) interpretations of data at the national level;

(iv) expert advice to other sectors of the national economy; and

(v) close co-operation with the Sudano-Sahelian Meteorological Centre.

B. Creation of a Sudano-Sahelian Meteorological Centre and Regional Training School providing:

(i) centralized services in stores supplies and instrument repairs and calibration;

(ii) centralized services in climatological data processing, summarization and publication;

(iii) sub-regional map compilation, research and investigations;

(iv) sub-regional longer-period forecasts; and

(v) training facilities for Classes II and III meteorologists and hydrologists.

External input	U.S. $ 1,000
National Meteorological Services:	
- networks of stations	1,500
- training: Class I	500
Classes II and III (provided under Regional Training School)	-
Class IV	100
- headquarters buildings and facilities	1,100
- expert advice during development	500
Sudano-Sahelian Meteorological Centre and Regional Training School:	
- buildings and facilities	1,400
- expert international staff first 5 years	1,800
	6,700

Description

Networks of stations

Synoptic meteorology has been developed since the second World War mainly for the protection of aviation. Some sparse networks of rainfall and climatological stations are directly under the control of Directors of Meteorological Services. Special projects executed by UN and other agencies provide data from scattered sites, mainly near the large river basins in the Sudanian zone.

In the six Sudano-Sahelian countries networks of three APT, seven upper air and 74 synoptic stations have been established for WWW and there are plans for improvement of these networks for the Global Atmospheric Research Programme Atlantic Tropical Experiment (GATE). But there are considerable gaps in the networks particularly in the northern Sahelian zone. For development of networks towards the target basic network of WMO Regional Association I (Africa) and to provide adequate data for all purposes, it is necessary to establish additional stations as recommended in the table below.

Agro-meteorological, hydro-meteorological and climatological stations are too few in number and are concentrated in the main river basins where special projects have been established at particular stations. If there is to be an understanding of the fundamental and practical problems of water resources and agriculture it is essential to establish planned networks of stations and to centralize collection of observations covering the zone as a whole. Provision must also be made for future special projects which are expected to be developed for water resources and agriculture and particularly for such projects in the northern pastoral zone.

Existing rainfall stations are insufficient in number and gaps in the networks are far too large for comprehensive study of the element which is of primary importance to socio-economic development in a semi-arid zone subject to extended drought.

Because of the local difficulties of obtaining observers and of maintaining instruments and providing communications, it is recommended that, wherever possible, stations should have multiple functions. Synoptic stations in the basic networks should fulfil the functions of agro-meteorological and climatological stations. Agro-meteorological stations should provide data on elements required for general meteorology. River flow and lake-level stations should in all cases make observations of rainfall and should also fulfil the functions of agro-meteorological and climatological stations wherever possible.

In many cases, especially in the south and in river basins, it will be possible to up-grade existing stations at relatively low cost in instruments, manpower and communications, but the establishment of many new ones is necessary. One country with an area over a million square kilometres now has 12 synoptic stations but has only one agro-meteorological station, four climatological stations, five river-flow observation stations and 13 rainfall stations. On the other hand, another country of less than 300,000 square kilometres has seven synoptic stations and over 200 rainfall stations. Even this latter density, averaging one rainfall station for each 1,500 square kilometres, cannot provide rainfall data adequate for agricultural and water-resources planning and management.

The following table gives recommendations for the number of stations required to provide data for all sectors of the economy and indicates possible additional requirements for stations for specific projects. This first assessment of the number of stations required has necessarily been approximate. It is recommended that a detailed survey of existing and necessary networks be made in each of the six countries. Such surveys would occupy one agro-meteorologist and one hydro-meteorologist, working together, over four months and should be regarded as a preparatory stage in the supply of expert advice in subsequent establishment of station networks and of headquarters of national Meteorological Services.

Analysis of approximate requirements* for basic networks of observing stations (up-grading or new)

Type of station	Haute-Volta	Mali	Mauri-tanie	Niger	Sénégal	Tchad	Cost US $ 1,000
APT	1		1	1			150
Radiosonde		1	1	1		2	600
Radiowind	1	1	1	1		2	
Synoptic		2	4			4	120
Agro-met.							
i) basic	10	20	10	10	10	20	250
ii) special projects	5	10	5	10	5	10	
Climatolog.							
i) basic	20	35	30	30	30	35	200
ii) special projects	5	5	5	5	5	5	
River flow & lake level							
i) basic	20	40	5	15	25	40	170
ii) Special projects	5	20	5	5	25	25	
Rainfall							
i) basic	60	250	200	200	50	200	70
ii) special projects	100	100	50	50	100	100	
						Total	1.560
						+ survey	25

* Requirements for new additional stations only are shown for APT, radiosonde, radiowind and synoptic stations. For all other types of stations the figures include both new stations and those which need up-grading to standards in the national network. In all cases figures are inclusive of those appearing against types of stations appearing higher in the table.

Stores supplies, instrument repairs and calibrations

Improvement and expansion of national networks of observing stations will make larger demands for the supplies and control of instruments and stores in the six countries. It would be economical and ensure standardization to provide for a major part of these functions, including an instrument workshop, in the Sudano-Sahelian Meteorological Centre.

Processing of climatological and hydrological data and their utilization

Commendable efforts have been made especially during the recent drought, by Directors of Meteorological Services and other agencies to collect and make use of data from diverse sources not all of which are usually collected or recorded in various existing publications.

Each national Meteorological and Hydrological Service needs to be provided with the staff and facilities for collection, verification, summarization and storage of all data made within its country.

National Services also need to supply summaries and interpretations of all data for rapid and general dissemination at the national level as well as to provide specialist advice on all meteorological and hydrological matters.

A Sudano-Sahelian Meteorological Centre is required to prepare data for computer processing and to publish permanent records, to interpret data on the regional scale by map compilation, research and investigation and to make longer-period forecasts.

Training

Attention must also be focussed on the necessity of increased numbers of national personnel for Meteorological and Hydrological Services of the Sudano-Sahelian countries. Existing numbers are small and, with few exceptions, the national meteorologists have a background of training and experience only in meteorology for aeronautical purposes. Moreover at the higher levels there is a large proportion of expatriates and of older men for whom replacements must be anticipated.

It is proposed that provision should now be made for training of African meteorologists and hydrologists at all levels. The full benefit of this training cannot be reaped for some years - in the late 1970's in the case of technical officers and about 1980 for higher professionals. Delays in starting projects for training can only result in retarded application of meteorology and hydrology to development of the countries.

Class I Meteorologists and Hydrologists

There are extremely few fully qualified professional meteorologists and hydrologists among the nationals of the Sudano-Sahelian countries. Whilst only about half of the six countries have any Class I professionals, each country needs a minimum of four in its national

Meteorological Service with specialization in climatology and in synoptic, agro- and hydro-meteorology. Some countries have fellows under long-term training overseas but the total is only half a dozen and the distribution between the six countries is unequal.

The Sudano-Sahelian Meteorological Centre would require 11 Class I professionals for sub-regional investigations and longer-period forecasts and the training of technicians.

It is proposed that 35 national holders of the "Baccalauréat" should be awarded long-term fellowships of 5 years each to obtain a degree in meteorology and to carry out post-graduate studies in general meteorology, agro-meteorology or hydro-meteorology.

The ultimate solution for education and training of Class I personnel would be the establishment of a Department or a Chair of Meteorology in a university of one of the Sudano-Sahelian countries. Alternatively Class I training facilities for West African students could be established in another French-speaking country in Africa. However, since the facilities in various fields of meteorological applications is a complex task and requires careful study, it is proposed that as an interim measure the long-term fellowships should be tenable abroad.

Class II and III Personnel

There are also very few Class II African meteorologists in the Sudano-Sahelian countries. Whilst the number of Class III officers working in the national Meteorological Service and the Regional Meteorological Centre at Dakar amounts to about 30, there is only about the same number in all the other five countries put together. Hydrologists are very few in number.

Such numbers will be inadequate for provision of meteorological services to all sectors of the economy. It is proposed that in conjunction with the Sudano-Sahelian Meteorological Centre there should be established a Regional Training School providing education and practical training for Classes II and III meteorologists.

During the first five years of operation the School should have an output of:

Class II 2 courses each of 12 students and of 24-30 months

Class III 4 courses each of 12 students and of 12-15 months

Class IV personnel

Although larger numbers of Class IV personnel are already available for synoptic meteorology there will be necessity for considerable additions not only to man the climatological, agro-meteorological and hydrological stations but also to provide for retirments. It would be difficult to envisage the training of these junior officers in one centre. It is proposed that a training expert should spend a period of about 6 months in each country to conduct local training of a total of about 120 Class IV personnel. This approach has already been carried out by WMO in other regions of the world with considerable success.

Establishment of Headquarters of National Meteorological Services

At present the headquarters of National Meteorological Services are, with few exceptions, accommodated with and very closely associated with aviation services.

Not only will the Meteorological Services require larger accommodation than is at present available but also the association of their activities with the Ministries of Rural Economy, Agriculture and Water Resources needs emphasis. The existing National Hydrological Services are already very closely associated with these Ministries and are accommodated in buildings attached to them.

It is proposed that new headquarters of National Meteorological Services should be dissociated from buildings used entirely for aeronautical services, where this is feasible and has not already been done, and that financial provision be made for new buildings, office equipment, libraries and vehicles for station inspections.

Expert advice in establishment of National Meteorological Services

The organization and development of National Meteorological and Hydrological Services require the laying of sound foundations in the early stages under guidance of fully qualified and experienced international experts.

In the description of the establishment of networks of stations it was proposed that one agro-meteorologist and one hydro-meteorologist should carry out a detailed survey of requirements in networks of stations and that this survey should be regarded as a preparatory phase in the supply of expert advice in subsequent establishment of the networks and of headquarters services of National Meteorological Services. To these experts should be added, at the implementation stage, two other experts - one in climatology and one in instruments. A further expert in synoptic meteorology might become necessary.

These four or five experts, working as a team, would be required over a period of about four years to give advice and assistance as progress and problems developed in establishment of national services. The experts would move into each of the six countries of the Sudano-Sahelian zone as circumstances demanded.

Establishment of Sudano-Sahelian Meteorological Centre and Regional Training School

A description of the necessity for a Regional Training School has been given under the section dealing with training of Classes II and III personnel. In the interests of economy, it is proposed that the School should share accommodation and professional staff with the Sudano-Sahelian Meteorological Centre.

Many of the meteorological problems of the Sudano-Sahelian zone are common to all six countries which have joined together in the Permanent Inter-State Committee for the Fight against Drought in the Sahel and which together have a total population of about twenty-five million people. Although each of the six countries needs the maintenance of networks of observing stations and provision of

service at the national level, there are some services, in addition to training, which can be appropriately provided to all countries from a sub-regional centre.

The Centre Inter-Africain d'Etudes Hydrauliques in Ouagadougou provides centralized services and co-ordination in hydrological services. The Regional Meteorological Centre and the Headquarters of ASECNA in Dakar provide centralized services and co-ordination in aeronautical and regional scale synoptic meteorology.

It is not proposed that this Centre should take over at an early stage some of the meteorological functions now being performed by other agencies because of gaps in meteorological organization. It may, however, become desirable for the Centre to be developed eventually into an organization responsible at the regional level for all general applications of meteorology and, in co-operation with other regional agencies, for meteorological activity in inter-disciplinary fields.

It is recommended that the Centre and School should be staffed by 11 experts, initally expatriate staff:

1 Director
1 Deputy Director
2 Synoptic Meteorologists
2 Climatologists
2 Agro-meteorologists
2 Hydro-meteorologists
1 Instrument technician

About one third of the working time of this staff should be devoted to training of Classes II and III students in the School.

Nationals of the six countries would be expected to replace expatriates as soon as adequate numbers of trained and experienced Class I African meteorologists became available.

Previous proposals for development of National Meteorological Services

In this appendix the development of National Meteorological Services in the Sudano-Sahelian countries has been dealt with as a whole since many of the problems arising in these countries are common to all of them. However, it is necessary to point out that, for some individual countries and some aspects of the general problems, separate proposals have been made elsewhere and some action has already been taken.

A UNDP project for the creation of a National Meteorological Service in Senegal (duration 4 years, $900,000) was started in April 1973. A UNDP project for development of agro-meteorological services in Mauritania (duration 1 year, $ 30,000) has been drawn up and submitted for approval. Some countries already have a few students in general meteorology, agro-meteorology and hydro-meteorology under training overseas. Such proposals and action should be taken as falling within and requiring co-ordination with the projects recommended in this document.

UNITED NATIONS

SECRETARIAT

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ST/SSO/20
1 February 1974

"NOT FINALIZED
LIMITED CIRCULATION"

THE VIEWS EXPRESSED IN THIS PAPER ARE THOSE OF THE DRAFTERS AND DO NOT NECESSARILY REFLECT THOSE OF THE UNITED NATIONS OR ANY OF ITS PROGRAMMES AND ORGANIZATIONS.

OUTLINE ANALYSIS FOR MINING SECTOR

SUDANO-SAHELIAN REGION

Special Sahilian Office

74-03167

MINERAL RESOURCES PROGRAMME
IN THE SAHELIAN REGION

I. The Problem

1. The inherent difficulties of any exploration (not alone exploitation) in arid or semi-desert areas, namely the scarcity of water, labour, and access roads, are compounded in the case of mineral exploration by certain limitations in the applicability of geochemical and geophysical methods, that is precisely those most suitable for the exploration of vast areas.

2. Mineral exploration is a very long-term undertaking, which external assistance can only help start. There are no (or no longer) jackpots; there is no predictable relationship between the amount of time and money spent and the results to be expected, if any. On the other hand, successful mineral exploration followed by mining development can provide a framework for a sectorial development of hitherto desert regions, as was the case in the Atacama desert in Chile, and, in the USSR, in Kazakhstan.

3. Those who decide, before deciding on an aid in mineral exploration, must be aware (or made aware) that they must be prepared to support a long-term effort (with incidental outside expertise only), in the form of permanent institutions and recurrent budgetary provisions (the latter in the form of overhead rather than new investment) and training programmes. Some disillusions will arise if no financial advantages are granted for work under hardship conditions.

4. [illegible] with metallic and certain industrial minerals. Coal and other solid fuels will be dealt with in the report on [illegible]

4. The rational planning of mineral exploration, whether local or regional, rests on the knowledge of all work done and all information gathered prior to inception. The United Nations does not possess that information in any comprehensive manner, nor do the recipient governments, as far as their countries are concerned. There are difficulties in obtaining it from certain bilateral donors. This is not to say that any further fieldwork has to await the availability of such full knowledge (proposals for such fieldwork are made in Annex III), but systematic data gathering is urgent.

5. The awareness of all the above by governments is necessary if they are to be able to appraise realistically the prospects of mineral exploration before they include them in their development plans or programmes, when financial and human resources are limited and anyhow, the countries have only a limited absorption capacity for development assistance.

6. An exception must be made in favour of locally available "common" materials suitable for local or regional industries. For their lack of glamour, they are too often disregarded, to the point of leading to substantial imports (see Annex I).

II. Significance of the mineral sector to the economy and its relationship to other economic sectors

1. Granted that large-scale, long-term development in the Sahel would best be based on the discovery of exploitable minerals for export, mostly metallics, it remains true that the probability for the mineral sector to become economically significant in the region is uncertain, except in regard of those "common" non-metallic minerals whose production could have an immediate bearing on local or regional needs. There are road-building and road stabilization materials, building construction materials, limestone, clays for pottery, bricks, tiles and pipes, marble, salt; perhaps also small metallic deposits that may be suitable for local processing by simple means. All these would lend themselves to the early development of local industries. Their assessment deserves high priority; aside from reducing imports, small industries are alternatives to complete reliance on animal husbandry and agriculture, and to the extent that they would reduce the demand on scarce water supplies and minimize the rate of encroachment of the desert due to the over-utilization of land.

2. Aside from this category, the significance of any mineral discovery will be affected by the long-term behaviour of the world market. Furthermore, any mineral occurrence, however attractive, will need confirmation by more refined exploration work and related economic studies, followed at the proper time by contract negotiations. All this may take years: in other words, market prospects aside, the future economic potential of any discovery will always be difficult to assess. Mineral rights granted to private parties

are by themselves meaningless in this respect, unless they are laid down in exploration and exploitation contracts where the mutual obligations are unequivocally spelled out, and the government is administratively equipped to enforce them.

Contribution of Mining Sector to Gross Domestic Product in the Sahelian Countries at Current Factor Cost, Converted at Current Year-to-Year Exchange Rates

(US $ Million)

Year	MALI		NIGER		SENEGAL		UPPER VOLTA		CHAD		MAURITANIA	
	Total GDP	Mining	Total GDP	Mining	Total GDP	Mining	Total GDP	Mining	Total GDP	Mining	Total GDP	Mining
1960	249.8		193.2		507.0	1.5	172.1		169.9		76.6	2.3[a]
1961	294.3		208.6		528.3	1.5	182.3		181.0	0.5	90.0	2.3[a]
1962	264.4		232.9		557.8	1.6	193.5		192.4	0.5	93.4	2.3[a]
1963	277.9		254.0		615.6	1.7	201.4		197.9	0.5	103.5	12.4[a]
1964	313.9	0.1	252.2		662.1	1.6	206.6		207.0		128.3	28.0
1965	352.6		283.6		677.0	1.6	205.8	0.9	219.4		142.9	36.0[a]
1966	390.9		298.4		699.6	2.3[a]	216.3	0.8	217.1		154.1	43.3[a]
1967	425.3		297.0		682.6	2.3[a]	228.4		218.3		162.0	45.0[a]
1968	453.4		274.5		727.4	2.3[a]	245.3		229.5		173.3	46.8[a]
1969	464.7		277.5		685.2	2.2[a]	258.2		233.4		173.2	50.6[a]

[a] Estimate of Economic Commission for Africa

Source: Economic Commission for Africa, Survey of Economic Conditions in Africa, 1970, Part II, United Nations, New York 1971.

III. Achievements in the past

1. The incomplete knowledge of the UN in respect of work done by others has been stressed in Section I.

2. Mineral projects (non-UN) having culminated in commercial-size production are few: iron and copper ore in Mauritania, phosphate ore in Senegal, uranium ore in Niger.

3. The specific achievements of UN-assisted projects are subject of Annex II. Their common characteristic is that however well planned and executed and however great the interest and support of the governments, none of these projects so far has led to actual investment and production. While in particular the Tambao manganese deposit in Upper Volta seemed originally very attractive, there is at present no known prospect of its early development.

C. Training

1. Training at the intermediate level (assistant geologists, drillers, mechanics, chemists) seems to be adequately ensured by in-service training in the course of field projects.

2. At the academic level (geologists, geochemists, geophysicists), a regional institution seems questionable, even if the programme should be conducted jointly with that for water resources development. Indeed the teaching staff would be heavy in regard of the real training needs if over-training is to be avoided. No specific training projects are therefore proposed.

V. Potential projects

A. Short-term actions

1. Exploration of metallic and non-metallic minerals

A comprehensive and costed programme, including non-metallics, is the subject of Annex III.

Road stabilization materials are the subject of a separate Annex IV.

B. Long-term actions

The actions described below are preparatory to long-term and rational planning of mineral development.

1. Complementary aerial photography

2. Complementary photogeological interpretation

The costing of these two operations must await information requested from French sources.

3. Fact-finding mission (Data collecting)

This would be a mission of two senior economic geologists, at least one of them versed in the geology and economics of local raw materials. They would collect and complete all information available on minerals in the Sahelian countries and their exploration, including to the extent possible information so far not available from certain bilateral programmes. Their consultations would take place in Paris (Bureau de Recherches géologiques et minières or BRGM, and Institut Géographique National).

London (Institute of Geological Sciences), Brussels (European Development Fund) and Washington (US Geological Survey and Bureau of Mines), and others as requested, as well as in each of the Sahelian countries. Private mining companies are also expected to cooperate, and at least one of them, Charter Consolidated, in London, has expressed its willingness to do so. The information sought would concern geology and mineral occurrences, surveys carried out and their results, with due regard to raw materials for local processing or consumption.

The mission would take not less than 6 months, at an estimated cost of $50,000.

The possibility should also be explored of contracting, for example with the BRGM, the establishment at UN Headquarters of a documentation center based on the large amount of material which that organization has already collected and indexed, and is still collecting.

Imports of non-metallic minerals in the Sahelian countries - 1968-1969

(Metric tons)

Countries		Cement	Salt	Clay non-refractory and clay products	Stone, sand and gravel	Gypsum	Fertilizers manufactured	Sulphur	Lime
Mali	1968-	26,008	12,535	-	40	-	3,260	-	-
	1969-	22,600	17,510	-	233	-	N.A.	-	-
Niger	1968-	503	-	228	-	-	178	-	-
	1969-	N.A.	-	167	-	-	16*	-	-
Senegal	1968-	2,629	18,315	-	682	-	31,339	-	-
	1969-	2,707	45,362	-	98	83	51,689	65	-
Upper Volta	1968-	2,650	-	234	-	-	-	-	-
	1969-	6,136	-	196	-	-	-	-	-
Chad	1968-	20,319	3,068	165	198	-	1,951	-	135
	1969-	12,703	3,178	187	9	-	438	-	176
Mauritania	1968-	5,634	5,275	201	-	-	3,131	-	-
	1969-	3,285	4,800	523	-	-	2,841	-	-

* Data on nitrogenous fertilizer not available for 1969.

Source: United States Department of the Interior, Minerals Yearbook 1970, Vol. III.

ANNEX II

Results of United Nations projects executed in the Sahelian zone

This annex briefly summarizes the main results obtained by United Nations projects in the Sahelian zone. The results are followed by recommendations, if any.

CHAD

United Nations Project CHD/72/002 (1973-1975): Mineral Exploration and Strengthening of the Geological Survey

UNDP Contribution: $630,750

Objectives:

Strengthening of the Geological Survey;

Construction of living quarters and laboratory;

Equipment and activation of the laboratory;

Geological reconnaissance in several parts of the country: proposed are mainly the Sahelian zones, which, however, due to unrest, will not be accessible.

Possible targets:

Based mostly on geological assumption and analogy as well as already localized indications the targets may be grouped as follows:

TIBESTI	Sn, Nb, Ta, Cu
MAYO-KEBBI	Au, Pt, Cu, Ni, Co, Cr, bauxite, limestone
ENNEDI	U, Zn, Cu, Pb (stratiform)
CHAD BASSIN	Diatomite, salines, phosphates
OUADDAI	Rare earths
GUERRA	Kaolin

Actually the project is located in the Southwestern part of Chad. The objectives are the reconnaissance for gold, platinum, carbonatite minerals, nickel, copper, cobalt related to ultrabasic rocks and non-metallics.

MALI

Mali (1970-1972): Exploration in the West of Mali (pre-project)

October 1970 - July 1972

UNDP Contribution: $186,325

Objectives:

Pre-project aiming at the applicability of reconnaissance methods (mainly geochemistry) in an area adjacent to the Senegal river project. The area covered is 42,000 km^2.

Results:

Cu-indications associated with:

a) dolerite dykes, weak and insignificant

b) quartz lenses, " " "

c) synsedimentary baryte, undetermined importance.

Baryte stratigraphically controlled, occurring at the contact of carbonate rocks. Undetermined economic value.

Pegmatite veins sometimes several km long and several meters thick. They have been found to carry spodumen. Value undetermined. The conclusions do not warrant a United Nations project. Some prospects for exploration do exist in the Birrimian basement, South of Kayes.

MAURITANIA

Mauritania MAU-4 (1971-1973): Strengthening of the Geological Service and Mineral Exploration

September 1971 - December 1973

UNDP Contribution: $420,794

Objectives:

Establishment of a functioning geological survey, procurement of the equipment and reconnaissance of a 100,000 km^2 territory in N.E. Mauritania.

Results:

The project carried out photogeological studies and geological reconnaissance in the area of the Dorsale de Regibat. Although the geological setting seemed a priori interesting, it turned out to be less than favourable. The area is composed of an old crystalline basement deeply eroded. The results were generally negative and one copper prospect examined (Blank) does not seem to be interesting.

Conclusion:

The local UNDP Resident Representative does not favour the continuation of the United Nations Mineral Survey.

NIGER

Niger: 2 1/2 years I and II phase project

October 1967 - March 1973

UNDP Contribution: $2,928,700

Results are not encouraging. The final report is currently in preparation.

SENEGAL

The United Nations assistance in the mineral survey of Senegal began in 1963 and extended over a period of 10 years. The third phase of this survey has just been completed in 1973.

SEN-7 (Phase I 1963-1965, Phase II 1965-1969): Mineral Exploration in Eastern Senegal

Phase I

January 1963 - October 1965

UNDP Contribution: $999,500

The project was initiated on the basis of an airborne geophysical survey. In the first phase, a general reconnaissance has been carried out.

Phase II

November 1965 - August 1969

UNDP Contribution: $566,300

In the second phase, the most important mineral indications have been evaluated.

a) Molybdenum showings in the region located between Kanémésé and Falémé. The results were completely negative.

b) Iron ore deposits of Mt. Kouroudiaho and Mt. Karakaéné were studied for eventual occurrence of base metal sulphides, with negative results.

c) Gold prospecting in several river basins indicated alluvial gold reserves totalling over 10 tons with grades from 0.2 to 1.5 gr/t however under substantial sterile overburden. Investigation of primary gold occurrences gave encouraging results. Two zones of quartz veins showed values from 4 to 25 gr/t and 2 to 75 gr/t respectively.

d) Prospecting for alluvial diamonds in Eastern Senegal was negative and there seem to be very poor chances for finding economically interesting kimberlite pipes.

e) Small concentrations of chromite have been discovered in the Gabou region in a large zone of basic and ultrabasic rocks so far, however, of negligible tonnage (2,000 - 4,500 T).

f) Interesting copper mineralization has been located within the zone of basic and ultrabasic rocks of Gabou. Borehole intersections indicated Cu values 0.5-2.5% plus 4 gr/t and 5 gr/t Ag.

Phase III

January 1970 - August 1973

UNDP Contribution: $410,000

A detailed assessment of the copper bearing zone Bakel-Gabou-Alinguel has been carried out.

a) It has been established that copper mineralization appears in a geologically favourable environment (deep fractures within volcano sedimentary formations). The values from boreholes gave 0.6 to 1.5% Cu, however, the complicated tectonics seem to diminish substantially the economic value of the prospected occurrences and no further exploration is recommended.

b) Limited nickel indications have been located within the zone of Gabou and their exploration is suggested.

UPPER VOLTA

The United Nations has been engaged in mineral exploration in Upper Volta since 1965, and has executed three mineral survey projects, (UPV-4, UPV-6, UPV-16) of which the last one was completed at the end of 1973. The government of Upper Volta has already requested the second phase for the current project to be extended until the end of 1975.

Summary of results:

Project UPV-4 (1965-1968): Exploration in the South-west of Upper Volta

UNDP Contribution: $1,003,139

a) Preliminary copper ore estimation in the Diemenera zone:

9,544,000 t Cu 1.38%

23,100,000 t Cu 0.5%

Mineralization: chalcopyrite, pyrite, minor molybdenite, gold 0.1-0.2 gr/t in altered, brecciated rocks forming linear (tabular) orebodies.

b) Gold in the Diebougon region, both alluvial and in primary quartz veins, is of no economic significance.

c) Diamond prospecting remained without firm conclusions. A few small diamonds both of gem and industrial quality have been found in several rivers in the project area and further prospecting has been proposed.

Project UPV-6 (1967-1970): Exploration in the Northeast of Upper Volta
(In the regions adjacent to the projected railway.)

November 1966 - September 1970

UNDP Contribution: $1,096,100

a) Detailed exploration of the Tsabuc manganese deposit.

11.5 million t of commercial Mn oxide ore with 54-55% Mn.

The mine development would require some US $8.5 million (1970 estimate) for the production of 575,000 t ore annually.

b) Exploration of Tin Hvasan limestones.

6 million t of limestone with 46% CaO suitable for the production of Portland cement. A proposition for 100,000 t/year cement factory was estimated between US$ 9-13 million.

c) Detailed exploration of vanadium-bearing, titaniferous magnetites in the Ourai-Tin Edia region. Several tens of million tons (50) of ore of lenticular occurrence average 45-50% Fe, 9-13% TiO_2 and 0.7% V_2O_5 (vanadium pentoxide). The testing indicated that ilmenite-magnetite cannot be readily separated mechanically and vanadium content alone is too low to be exploitable.

d) Exploration of high quality bauxites in the Kaya-Kongoussi region. Bauxites suitable for production of refraction and abrasive materials (Al_2O_3 53%, Fe_2O_3 3%, TiO_2 3.5%) were located in 17 small deposits, totalling some 6 million tons. A group of 3 such deposits with 3 million tons of reserves has been estimated as an economic proposition for an annual production of 100,000 tons of calcinated bauxite. Estimated investment: US$ 3 million.

e) Exploration of gold occurrences at Gangaol (Dori).

Two zones of quartz veins (500 and 750 m long and 1.5 m wide) average 1.8 gr Au/t and 2.3 gr Ag/t is not an economic proposition at present.

f) Geochemical prospecting for base metals has located zinc-copper anomalies in the Gan-Kiembara region and nickel anomalies in the North of the Dori region.

Project UPV-16 (1970-1973): Mineral Exploration in the North
(Continuation of prospecting in the regions adjacent to the proposed railway.)
January 1971 - December 1973
UNDP Contribution: $1,169,900

a) Zone of weak copper mineralization, however, in promising geological environment, has been located in Mogtodo region.

Second phase of the current project: is planned in essentially the same region and with mainly the same objectives (general reconnaissance). It is hoped that by that time the results of the airborne geophysical survey carried out with the CIDA (Canadian) assistance will be available and will provide new targets.

ANNEX III

A comprehensive programme of mineral exploration for the Sahelian Region

A. History

1. The African Sahelian and desert regions are underlain by rocks with which, in other more accessible parts of Africa, numerous and varied mineralizations are associated. It is possible that important mineral deposits may be located in the Sahel if the necessary investments are made in mineral exploration for metallic and non-metallic ores.

2. Since antiquity, salt has been mined in Mali and in Chad. This mining has continued on an artisanal scale until now. Gold has been worked on what was called the Bambouk plateau in Mali, in Senegal as well as in Ivory Coast and Guinea for a very long time (possibly since the Pharaonic period). More recently iron has been worked by the inhabitants in Senegal, Mauritania and Mali. In Niger there are indications of very old copper exploitation in the region located West of Air.

3. Prior to 1960, the Sahelian region was geologically mapped and explored in a preliminary manner for diamonds, gold, tin, uranium, tungsten, niobium and tantalum. Beryl and lithium ores have been prospected in Mali and Senegal, and phosphates and iron ores have been investigated nearer the sea in Senegal and Mauritania. In Senegal, Mali, Upper Volta, Niger and Chad, gold has been mined in placer deposits, and in some instances in quartz veins. In the Air region of Niger, tin was mined during the Second World War and mining still continues on an artisanal scale. In the same region, uranium deposits were discovered and are in production now (1,000 tons

a year). In Senegal, important phosphate mines are exploited (1.5 million tons a year) and iron ore (up to 10 million tons a year) and copper (200 tons a year) are mined in Mauritania. In Upper Volta large manganese deposits (12 million tons) have been located but are not yet exploited.

4. After 1960, mineral surveys were conducted mainly by French (Bureau de Recherches géographiques et minières or BRGM), USSR, Canadian and Polish bilateral aid programmes and on a limited scale by private concerns. This exploration has located some mineral indications but as yet no mineral deposits. The UN completed the evaluation of the manganese deposits of Tambao in Upper Volta but on the whole the UN mineral survey projects conceived in the early 1960s were terminated without significant results (see details in Annex II). Indeed at that time, the use of geochemistry, airborne geophysics, photogeology and geochemistry had not yet been introduced to its present extent, and was not then as accurately understood as it is now. Also, many views on the relationship between tectonic fractures and mineralization have evolved. A full understanding of African volcano sedimentary formations is only now beginning to emerge, leading to the realization that these formations may be considered as "green stone" belts similar to those of Canada, Australia and South Africa, with possibilities of "massive sulphide" deposits, disseminated stratabound sulphide deposits and porphyry type copper and molybdenum deposits.

5. It is true that the work of BRGM as well as that of the UN projects have already located, in relation to these formations, numerous indications of copper, molybdenum, nickel, cobalt, lead and zinc. But these indications

need now full-scale revision and updating by experts familiar with such types of mineral deposits and able to interpret in the light of existing models, the messages given by geology, geophysics and geochemistry.

Mercury, antimony and baryte indications have been located on the Precambrian basement and they indicate possibilities of low temperature mineralizations related to fracturing of the Precambrian African Platforms. In the course of the UN and BRGM investigations certain possibilities may have remained unchecked.

Copper, lead and zinc mineralizations were located by BRGM and by UN projects on the contacts of the Precambrian basement with sedimentary formations in Mauritania, Mali, Upper Volta and Niger. However, these mineral indications were not fully investigated and the zones of contact between the basement and sedimentary formations not systematically explored. In the last few years, again, ideas and concepts on the location of strata-bound mineral deposits in sedimentary formation, on contacts with the basement, and on techniques of investigating them have evolved, and begun to be put into practice. The recent ideas on these types of deposits open new, wide fields for investigation.

6. Furthermore there are regions such as the Adrar des Iforas, AÏr and Tibesti which because of their difficult accessibility have never been completely explored for mineral possibilities.

7. Non-metallic mineral wealth has received little attention, especially in remote parts of the Sahel, yet there is an evident need for such commodities as clays for bricks, tiles, kaolins, and building stones; limestone for lime, possibly cement, and building purposes. Found along the coasts and railroads,

marbles and good quality granites, syenites and black basic and ultrabasic rocks suitable for polishing may be important; given the fact that for prime quality material, several hundred dollars per ton may be obtained on European markets.

8. It may be concluded from the above that perhaps only a minor part of the mineral potential has been investigated in the Sahelian region, and in any case that in the field of mineral exploration the Sahelian countries have important common problems, which it is recommended to solve in two general phases.

9. The first phase should include mineral investigation programmes according to latest concepts and techniques in the field of mineral exploration. The second phase should be designed for the execution of projects resulting from the results of the first phase.

B. Mineral objectives of the First-Phase Programme
(See country-by-country programmes under C.)

(a) The indications of mineralizations such as copper, molybdenum, nickel, cobalt, lead and zinc already discovered and related to the volcano sedimentary formations as well as to the facies of these formations should be studied and reviewed in the light of new concepts on green stone belt mineralizations. Programmes for further exploration of these mineralizations and formations should be formulated and budgetted. Such a review should be undertaken by highly specialized experts.

(b) The mineralizations of copper, lead and zinc related to contacts between basement and transgressive sedimentary formations in Mauritania, Senegal, Mali, Upper Volta, Niger and Chad should be reviewed. Programmes should be prepared for the investigation of zones of contact as well as for the study of stratabound mineralizations, metallic and non-metallic mineralizations that may be associated with sedimentary formations.

(c) The Sahelian region should be studied in terms of global tectonics to outline the possibilities of mineralizations related to fracturing and the reactivation of the old Precambrian Platforms. Similar studies of Russian, Siberian and Chinese platforms have proved to be very fruitful and have led to the discovery of numerous mineral deposits.

(d) Numerous gold placers and some quartz veins have been worked for coarse gold throughout the Sahelian region. They must now be reviewed for the possibilities of finely dispersed or colloidal gold. Geochemical exploration methods may be applied in further investigation and reassessment of the possible potential of these deposits.

(e) Numerous basic and ultrabasic intrusions or complexes exist in Sahelian countries. Until now, little attention has been paid to these rocks, but they may be associated with nickel, copper and other types of mineralizations. They should be carefully reviewed by specialists.

(f) Remote regions with acidic intrusions such as Adrar des Iforas in Mali, Air region in Niger and Tibesti in Chad, should be reinvestigated for their possibilities of tin, tungsten, niobium, tantalum and beryl as well as uranium. The recent volcanic formations of Tibesti should also be

examined for possible related mineralizations. Structural features should be studied, as should the possibilities of mineralizations of low temperature associated with volcanic activity.

(c) Non-metallics should include the study of the possibilities for building stones, and particularly for stones suitable for polishing, along the railroads and major roads; and the prospects for clays, kaolins, feldspars, limestones and building stones should be investigated.

Such reviews may only outline the programmes of the projects to be undertaken, though it cannot be excluded that they may lead to discoveries of workable mineral deposits only if they are sufficiently financed and staffed with competent personnel.

(b) A major part of existing geological data was collected long ago, frequently only for geological mapping and at a time when most present-day concepts on the significance of volcano sedimentary formations, on strata-bound mineral deposits, and on relations of mineralizations to different structural factors had not yet evolved.

Therefore a mere review and re-interpretation of the existing documentation can hardly lead to significant conclusions and recommendations. New field investigation and analyses should be performed with greater emphasis than in the past on regional features. For these reasons, even the first phase will be relatively expensive.

C. Work to be undertaken in each of the Sahelian countries

The overall programme outlined under B can be tentatively broken down geographically as follows:

1. MAURITANIA

(a) review of the volcano sedimentary formations with which copper and copper molybdenum mineralizations are associated;

(b) assessment of the mineral potential of the contacts of the basement and the sedimentary formations north and south of the "Dorsale de Regiat". Lead and zinc mineralizations have already been located along the contacts and their general significance should be assessed;

(c) the structural features of Mauritania should be studied with a view to suggesting possible mineral associations;

(d) ultrabasic rocks should be reviewed for their possibilities of copper, nickel, cobalt and platinum;

(d) Mauritania has a railroad and sea port so that dimension stones suitable for polishing should be examined as well as all other non-metallics suitable for export or local use.

2. MALI

The same type of studies as for Mauritania will be required, for volcano sedimentary formations, for the contacts of basement sedimentary formations, for basic and ultrabasic rocks, for general structures that may be associated with mineralisations as well as for non-metallics. Mali has had gold exploitations but the results have to be revised for their

possibilities of dispersed gold. Acidic rocks and associated mineralizations particularly those of Adrar des Iforas have already been studied by French and Russian geologists, but deserve being studied anew. They must be examined particularly as to whether there are no albitized cupolas with niobium, tantalum and beryllium mineralizations.

3. UPPER VOLTA

A project is already being executed in Upper Volta, but the review of its results by a team of highly qualified and specialized experts may prove to be of outstanding interest. Moreover, in the South-Western part of Upper Volta interesting indications of porphyry copper mineralizations in relation to volcano sedimentary formations have already been studied, although perhaps their implications have not been fully understood.

In the same region there are old gold workings that deserve close examination for dispersed gold. A study of structures in the South-Eastern part of Upper Volta has already led to the location of interesting copper indications. These studies should be extended to the whole of Upper Volta and especially to its South-Western part.

Along the Northern, Western and Southern borders of Upper Volta contacts run between the basement and transgressive sedimentary formations. Interesting mineralizations of copper and lead and indications of zinc have already been located along these contacts and the whole length should be carefully examined. The ultrabasic and basic rocks of the project area, as well as of other parts should be checked for their possibilities of copper, nickel, cobalt and platinum mineralizations.

The problem of non-metallics is the same as for Senegal and Mauritania. It must be underlined that Ivory Coast has already implemented an industry of polished granitic rocks and that in Togo marbles are in production and a cement plant is under study. Certain types of syenitic and granitic rocks in Upper Volta are suitable for polishing and may be transportable to the port of Abidjan.

4. SENEGAL

Senegal has the same problems as Mauritania, but does have old gold workings which should be examined for dispersed or colloidal gold.

The question of non-metallics should receive particular attention.

5. NIGER

Niger needs a completely fresh look at its mineral possibilities, particularly the Aïr region. All the above-mentioned reviews may be undertaken on Niger territory.

6. CHAD

The Aïr and Zinder areas have to be surveyed for mineralizations related to acid magmatism and should be carefully studied in terms of mineralizations that may be related to tectonic structures for which a study should be undertaken. The sedimentary formations surrounding these areas should be investigated for stratabound mineral deposits such as uranium, copper, lead, zinc, etc.

The Liptako region should be studied in the same way as has been outlined for Upper Volta and Mali, for its structural features as well as for mineral possibilities of the volcano sedimentary Birrimian formations.

D. Budget

A budget for this preliminary phase is outlined in the following table I.

Table I

BUDGET

	Man-Months	$ Total	$ 1975	$ 1976
1. EXPERTS:				
- Project Manager	24	60,000	30,000	30,000
- Specialist in green stone belt mineralizations (2)	48	120,000	60,000	60,000
- Specialist in stratabound deposits (2)	48	120,000	60,000	60,000
- Specialist in mineralizations (copper, nickel, cobalt, platinum, gold) related to the basic and ultrabasic rocks (1)	24	60,000	30,000	30,000
- Specialist in relationship of tectonic structures and mineralizations (1)	24	60,000	30,000	30,000
- Specialist in mineralizations related to acid magmatism (1)	24	60,000	30,000	30,000
- Specialist in dispersed gold mineralizations	24	60,000	30,000	30,000
- Specialist in non-metallics (2)	48	120,000	60,000	60,000
- Pilot (1)	24	60,000	30,000	30,000
Total experts -	288	720,000	360,000	360,000

	Man-Months	$ Total	$ 1975	$ 1976
2. SUPPORT PERSONNEL:				
- Accountant (1)	24	12,000	6,000	6,000
- Bilingual Secretary (1)	24	12,000	6,000	6,000
- Typists (2)	48	12,000	6,000	6,000
- Draftsman (1)	48	12,000	6,000	6,000
- Drivers (10)	120	24,000	12,000	12,000
- Miscellaneous personnel (10)	120	24,000	12,000	12,000
Total support personnel -	384	96,000	48,000	48,000

	US $
3. SUB-CONTRACTS:	
- Computerized collection of data	25,000
- Chemical analyses	25,000
- Mineralogical and petrographical analyses	10,000
Total sub-contracts -	60,000
4. EQUIPMENT:	
a) expendable	
- office furniture and equipment	30,000
- spare parts for vehicles	40,000
- camping equipment	10,000
- air conditioners	20,000
- miscellaneous	20,000
- fuel and oil	100,000
Total expendable equipment -	170,000

	US $
b) non-expendable	
- vehicles (12)	50,000
- aircraft (aircommander)	150,000
Total non-expendable equipment -	200,000
5. MAINTENANCE:	
- vehicles and aircraft	50,000
6. RENTING OF OFFICES	50,000
7. INTERNAL TRAVEL	50,000
8. MAIL AND CABLES	10,000
9. MISCELLANEOUS	15,000

SUMMARY

	Man-months	US $
Experts	288	720,000
Support personnel	96	96,000
Sub-contracts		60,000
Equipment:		
Expendable		170,000
Non-expendable		200,000
Maintenance - vehicles and aircraft		50,000
Renting of offices		50,000
Internal travel		50,000
Mail and cables		10,000
Miscellaneous		15,000
TOTAL COST IN DOLLARS		1,421,000

E. Follow-up

It is expected that at least ten national or regional projects would stem from this first phase study, and in turn need at least another $15,000,000 for a perioa of three years. Again for several of these projects subsequent phases may be needed, so that a conservative figure for the global investigation of the mineral potential of the Sahelian region at 25 million dollars could be spent over a five-year period or more, including all the work specified in Section V and Annex IV of this report.

ANNEX IV

Road stabilization materials
(by the Transport Section)

1. There is very limited need for expertise in geology and mining in connexion with common highway materials or their laboratory control. When a highway is being built, bank-run, base courses, and construction aggregates are usually obtained within or near the project's right of way. The highway is normally designed in function of available materials which are first identified and subsequently controlled through very standardized geotechnical procedures. The discipline of geology plays virtually no role in this process.

2. There is on the other hand a pressing need, not only in the Sahel but everywhere, to identify local materials which may be suitable to replace conventional highway materials such as asphalt or cement, and to determine their suitability range through laboratory tests. The recurring problem is invariably to modify or improve the characteristics of locally available soil materials through the mechanical, chemical, or electro-static action of additives. The characteristics to be altered include shear cohesion, permeability, plasticity, swell, and others associated with the material's origin, weathering and state.

3. The problem as we see it, is to identify potential additives in the course of broad geological exploration, then to ascertain the purposes for which the additives can be used and the methods to be followed for such use.

4. Several potential additives come to mind in connexion with the Sahel. They include natron, decomposed granites and scoriae, pozolanic soils, gypsum, and lime. We stress it however, that the terms of reference for any geologic explorations should provide for asking two questions in connexion with highways. First what materials are available? Second, what can these materials be used for, and how?

5. Identification and quantification of materials should be a first order of priority. Requirements in this connexion would include participation in the exploration team of a geologist specialized in geotechnics and allied chemistry. Modest, portable field testing facilities would be required.

6. The second order of priority would include assessment of materials and of their use through laboratory testing. The laboratory would not necessarily need to be established in the project area since samples could be shipped for testing over comparatively large distances.